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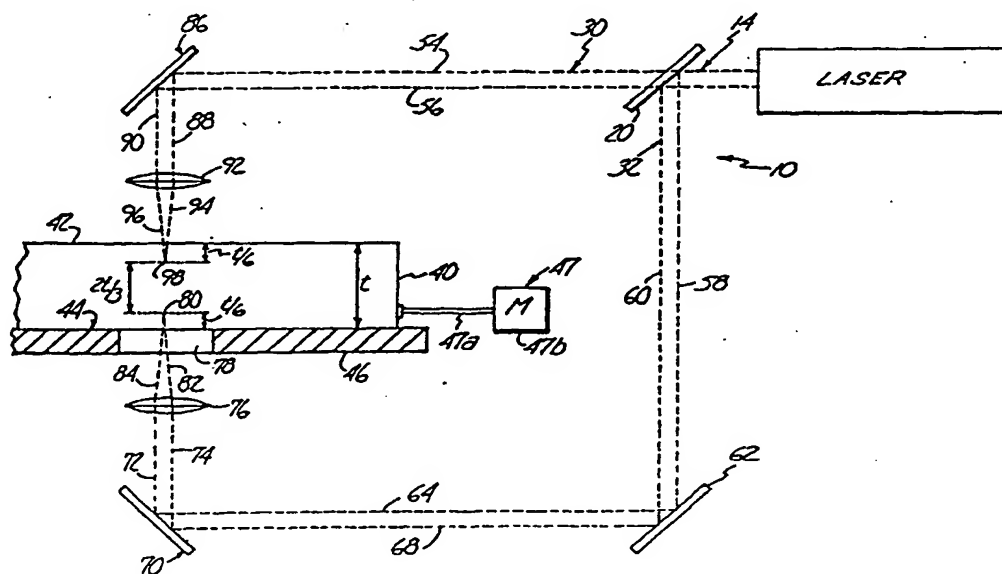
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(21) International Application Number: PCT/US94/10489 (22) International Filing Date: 15 September 1994 (15.09.94) (30) Priority Data: 08/125,922                      23 September 1993 (23.09.93)    US (71) Applicant: LASER MACHINING, INC. [US/US]; 500 Laser Drive, Somerset, WI 54025 (US). (72) Inventor: LAWSON, William, E.; Somerset, WI (US). (74) Agents: SAWICKI, Z., Peter et al.; Kinney & Lange, P.A., Suite 1500, 625 4th Avenue South, Minneapolis, MN 55415-1659 (US).	(81) Designated States: CA, JP, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  Published With international search report.	

(54) Title: LASER CUTTING APPARATUS



(57) Abstract

An apparatus (10) for cutting a material (40) having a thickness, T, defined by the distance between a first surface (46) and a second surface (42) of the material (40). The apparatus (10) comprises an energy source (12) for providing a beam of energy (14), and directing mirrors for directing the beam of energy from the energy source to a first focal point (80) between the first and second surfaces (46, 42) of the material, and to a second focal point (98) between the first and second surfaces (46, 42) of the material (40). The first and second focal points (80, 98) are spaced apart from each other by a distance sufficient to cut through the entire thickness of the material (40).

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**LASER CUTTING APPARATUS**  
**BACKGROUND OF THE INVENTION**

The present invention relates to a cutting apparatus, and more particularly, to a laser cutting apparatus which focuses multiple laser beams on  
5 a material to be cut.

Today laser cutting apparatuses and methods for cutting thick materials, such as wood having a thickness greater than one inch or plastic having a thickness greater than two inches, generally involve the use a single high-powered laser which produces a single beam of energy which is directed at  
10 the material. The use of a high powered lasers necessitates the use of a long focal length lens which produces a large, undefined focal point on the material, and consequently a wider kerf. The large focal point and wide kerf result in a greater amount of material being vaporized and therefore a slower cut. For some material, such as two inch plexiglass, the cut is almost impossible using a single,  
15 conventional laser beam.

Multiple laser beams have been used in a cutting applications, as exemplified by U.S. Patent 4,761,535 to Lawson. Lawson relates to a laser wire stripper which uses a single laser which is directed and focused to a first point, and then directed to a curved reflector where it is refocused to a second point  
20 that is displaced from the first point by an amount which permits the insertion of a stripable wire between the two points. The beams cut the wire insulation from alternate sides while the wire is being moved along a line between the two points.

Lawson also discloses a wire cutter apparatus using a single laser  
25 which is split into opposing beams by a beam splitter. The opposing beams are directed to opposing sides of the wire and focused at the center of the wire for cutting the insulation from the wire, but not the wire itself. Lawson indicates that the focal points may be moved apart from one another.

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### SUMMARY OF THE INVENTION

The present invention relates to an apparatus for cutting a material having a thickness,  $T$ , defined by the distance between a first surface and a second surface of the material. The apparatus comprises energy source means  
5 for providing a beam of energy, and directing means for directing the beam of energy from the energy source means to a first focal point between the first and second surfaces of the material, and to a second focal point between the first and second surfaces of the material. The first and second focal points are spaced  
10 apart from each other by a distance sufficient to cut through the entire thickness of the material. Preferably, the first and second focal points are spaced apart from each other by a distance equal to two-thirds of the thickness of the material, the first focal point is spaced apart from the first surface by a distance equal to  
15 one-sixth of the thickness of the material, and the second focal point is spaced apart from the second surface by a distance equal to one-sixth of the thickness of the material.

### BRIEF DESCRIPTION OF THE DRAWING

The sole Figure is an elevational view of a laser cutter according to the present invention and a cross section of a material to be cut.

### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

20 Referring to the Figure, a cutting apparatus 10 includes a single, fixed energy source 12, for providing a single beam 14 of energy, a beam splitter 20 for splitting the single beam 14 of energy into a first beam 30 and a second beam 32, and optics for reflecting and focusing the beams 30 and 32 to points within the material 40. The material 40 has a top surface 42, a bottom surface  
25 44, and a thickness,  $t$ , defined as by the distance between the top surface 42 and the bottom surface 44. The material 40 is supported on a table 46. The material 40 is moved relative to the focused energy beams 30 and 32 to produce a cut by a motive mechanism 47 including a solenoid 47a having a drive pin 47b for

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moving the material 40 relative to the table 62. However, it is to be understood that the beams 30 and 32 may be moved relative to a stationary material 40.

5 A preferred energy source, a CO<sub>2</sub> laser 6, is shown projecting the single beam 14 of energy along a path shown by lines 50 and 52. Other energy sources, such as lasers which produce ultra-violet or infrared energy may be used depending on the characteristics of material 40. The beam splitter 20 is a partially silvered mirror which divides the single beam 14 into the first beam 30 which is projected along a path shown by lines 54 and 56, and into the second beam 32 which is projected along a path shown by lines 58 and 60. The angle of incidence of the single beam 14 on the beam splitter 20 is directly proportional to the amount of energy in the first and second beams 30 and 32. Preferably, the first and second beams 30 and 32, are of equal power, equal to one half the power of the single beam 14. Additional energy sources 12 may be employed to obviate the use of the beam splitter 20, each of which contains a portion of the power of the single beam 14. This may provide advantages as the beam quality and focusability is better for smaller lasers.

10 The energy beam 32 projected along the path shown by lines 58 and 60 is reflected by a 100% reflective mirror 62 and continues along a path shown by lines 64 and 68. The energy beam 32 is further reflected by a 100% reflective mirror 70 along a path shown by lines 72 and 74 to a lens 76 which focuses the energy through hole 78 in the table 46, to a focal point 80 shown as the intersection of lines 82 and 84. The focal point 80 is located below the bottom surface 44 of the material 40 and within the material 40. The perpendicular distance between focal point 80 and bottom surface 44 is approximately equal to one-sixth of the total thickness  $t$  of the material 40.

25 The energy beam 30 projected along the path shown by lines 54 and 56, is reflected by a 100% reflective mirror 86 to a path shown by lines 88 and 90. The energy beam 30 is subsequently focused by lens 92 along lines 94

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and 96 to focal point 98 below the top surface 42 of material 40, which is geometrically homologous to focal point 80 below the bottom surface 44 and within material 40. The perpendicular distance from focal point 98 to the top surface 42 is approximately equal to one-sixth of the total thickness  $t$  of the material 40. Consequently, focal point 80 is located a distance approximately two-thirds of the thickness  $t$  from focal point 98. Although the preferred embodiment uses a spacing distance between foci 80 and 98 of two thirds the total thickness  $t$  of the material 40, with each focal point being located a perpendicular distance below its respective surface equal to one-sixth the total thickness  $t$  of the material 40, the location of the foci 80 and 98 and their distances from each other and from the top and bottom surfaces 42 and 44 may be changed in consideration of energy distribution requirements, characteristics of the material 40, or other factors relating to the speed, thickness, or kerf of the desired cut. For most materials, the perpendicular distance between foci 80 and 98 and the top and bottom surfaces 42 and 44 is between one-sixth and one-quarter the thickness  $t$  of the material 40, and the perpendicular distance between foci 80 and 98 is between two-thirds and one-half the thickness  $t$  of the material 40.

The energy focused at points 80 and 98 vaporizes the material 40 between the top and bottom surfaces 42 and 44 and along a kerf line defined by focal points 80 and 98, to produce a continuous cut completely through the material 40. The motive mechanism 47 including a screw 47a attached to the material 40 and motor 47b for driving the screw 47a move material 40 through the energy beams 30 and 32 focused at points 80 and 98. However, any relative motion between the material 40 and the energy beams 30 and 32 will propagate this cut along a path defined by the relative motion.

Using lower powered beams 30 and 32 (compared to the power of the single beam 14) and two lenses 76 and 92 on opposite sides of the

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material, permits the energy beams 30 and 32 to be focused more narrowly than if a single high-powered laser beam was used. For example, two lasers each with 3kw of power, focus much better than a single 6kw laser due to a lower times diffraction-limit number,  $M^2$ . This results in less material being vaporized, a narrower kerf and consequently, a faster cut. Thus, with opposing laser beams 30 and 32 cutting at separated foci, it becomes possible to cut the same size sample more quickly than with a single laser beam using a longer focal length lens. It further becomes possible to cut samples which are too thick to be cut at all with a single beam. Workers skilled in the art will recognize that additional energy beams and/or splitters may be employed to focus additional laser beams in the cutting plane for cutting the material 40.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

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WHAT IS CLAIMED IS:

1. An apparatus for cutting a material having a thickness, T, defined by the distance between a first surface and a second surface of the material, the apparatus comprising:
  - 5 energy source means for providing a beam of energy; and  
directing means for directing the beam of energy from the energy  
source means to a first focal point between the first and  
second surfaces of the material, and to a second focal  
point between the first and second surfaces of the material,  
10 the first and second focal points being spaced apart from  
each other by a distance sufficient to cut through the  
entire thickness of the material.
2. The apparatus according to claim 1, further comprising motive  
15 means for moving the material with respect to the energy source means.
3. The apparatus according to claim 1, wherein the energy source  
means includes a laser.
- 20 4. The apparatus according to claim 3, wherein the laser produces  
infrared energy.
5. The apparatus according to claim 3, wherein the laser is a CO<sub>2</sub>  
laser.  
25
6. The apparatus according to claim 3, wherein the laser produces  
ultraviolet energy.



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7. The apparatus according to claim 1, wherein the directing means includes a beam splitter for splitting the beam of energy from the energy source means into a first beam of energy operable with the first focal point and into a second beam of energy operable with the second focal point.
- 5 8. The apparatus according to claim 7 wherein the first and second focal points are spaced apart from each other by a distance equal to two-thirds of the thickness of the material.
- 10 9. The apparatus according to claim 7, wherein the first focal point is spaced apart from the first surface of the material by a distance equal to one-sixth of the thickness of the material, and wherein the second focal point is spaced apart from the second surface of the material by a distance equal to one-sixth of the thickness of the material.
- 15 10. A method of cutting a material having a thickness of at least one inch, the method comprising:
- providing a first beam of laser energy;
  - providing a second beam of laser energy;
  - 20 directing the first beam of laser energy towards a first surface on the material to be cut;
  - directing the second beam of laser energy towards a second surface on the material to be cut;
  - focusing the first beam of laser energy to a first focal point within the material between the first and second surfaces;
  - 25 and
  - focusing the second beam of laser energy to a second focal point within the material between the first and second surfaces;

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the first and second focal points being spaced apart from each other a sufficient distance to cut completely through the material.

5     11.            The method of claim 10 further comprising the step of moving the material with respect to the energy source means.

12.            The method of claim 10 wherein the energy source means includes a laser.

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13.            The method according to claim 12 wherein the laser produces infrared energy.

14.            The method of claim 13 wherein the laser is a CO<sub>2</sub> laser.

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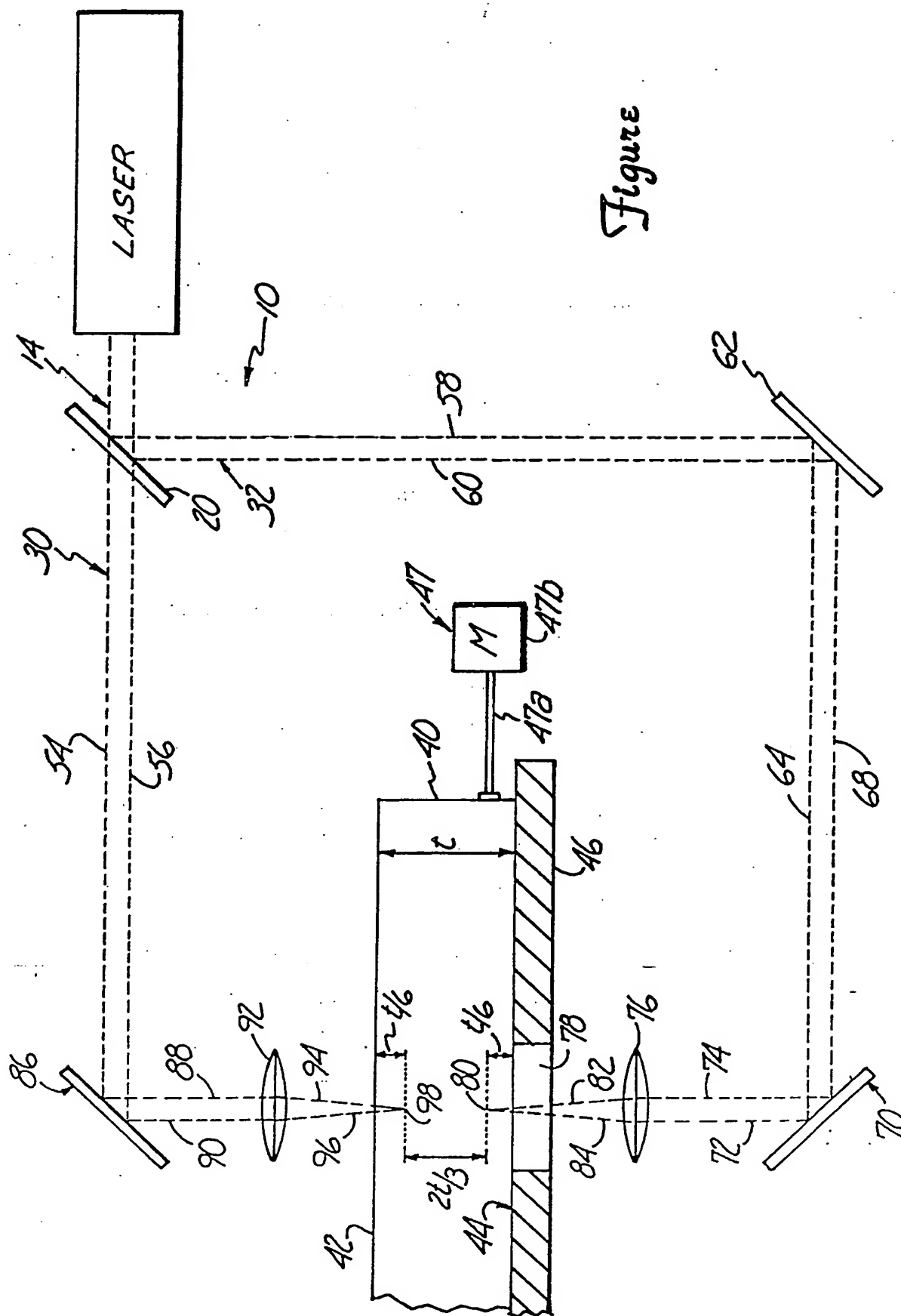
15.            The method according to claim 12 wherein the laser produces ultraviolet energy.

16.            The method of claim 12, wherein the first and second focal points are spaced apart from each other a distance equal to two-thirds of the thickness of the material.

20

17.            The method according to claim 12, wherein the first focal point is spaced apart from the first surface of the material by a distance equal to one-sixth of the thickness of the material, and wherein the second focal point is spaced apart from the second surface of the material by a distance equal to one-sixth of the thickness of the material.

25



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US94/10489

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B23K 26/00, 26/02

US CL :219/ 121.67, 121.72 , 121.76, 121.77, 121.79

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 219/ 121.67, 121.72 , 121.76, 121.77, 121.79

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 4,761,535, (Lawson) 02 August 1988, see entire document	1-17
X	US, A, 4,931,616, (Usui et al) 05 June 1990, see entire document	1-17
X	US, A, 4,146,380, (Caffarella et al) 27 March 1979, see entire document	1-17
X	US, A, 4,794,231, (Banas et al) 27 December 1988, see entire document	1-17

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Further documents are listed in the continuation of Box C.

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See patent family annex.

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